Nearby early-type galaxies with ionized gas^{*,**}

I. Line-strength indices of the underlying stellar population^{***}

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Abstract. With the aim of building a data-set of spectral properties of well studied early-type galaxies showing emission lines, we present intermediate resolution spectra of 50 galaxies in the nearby Universe. The sample, which covers several of the E and S0 morphological sub-classes, is biased toward objects that might be expected to have ongoing and recent star formation, at least in small amounts, because of the presence of the emission lines. The emission is expected to come from the combination of active galactic nuclei and star formation regions within the galaxies. Sample galaxies are located in environments corresponding to a broad range of local galaxy densities, although predominantly in low density environments.

Our long-slit spectra cover the 3700–7250 Å wavelength range with a spectral resolution of ≈ 7.6 Å at 5550 Å. The specific aim of this paper, and our first step in the investigation, is to map the underlying galaxy stellar population by measuring, along the slit positioned along the galaxy major axis, line-strength indices at several, homogeneous galacto-centric distances.

For each object we extracted 7 luminosity-weighted apertures (with radii 1.5'', 2.5'', 10'', $r_e/10$, $r_e/8$, $r_e/4$ and $r_e/2$) corrected for the galaxy ellipticity and 4 gradients ($0 \leq r \leq r_e/16$, $r_e/16 \leq r \leq r_e/8$, $r_e/8 \leq r \leq r_e/4$ and $r_e/4 \leq r \leq r_e/2$). For each aperture and gradient we measured 25 line-strength indices: 21 of the set defined by the Lick-IDS "standard" system (Trager et al. 1998, ApJS, 116, 1) and 4 introduced by Worthey & Ottaviani (1997, ApJS, 111, 377). Line-strength indices have been transformed to the Lick-IDS system. Indices derived then include H β , Mg₁, Mg₂, Mgb, MgFe, Fe5270, Fe5335 commonly used in classic index-index diagrams.

The paper introduces the sample, presents the observations, describes the data reduction procedures, the extraction of apertures and gradients, the determination and correction of the line-strength indices, the procedure adopted to transform them into the Lick-IDS System and the procedures adopted for the emission correction. We finally discuss the comparisons between our dataset and line-strength indices available in the literature.

A significant fraction, about 60%, of galaxies in the present sample has one previous measurement in the Lick-IDS system but basically restricted within the $r_e/8$ region. Line-strength measures obtained both from apertures and gradients outside this area and within the $r_e/8$ region, with the present radial mapping, are completely new.

Key words. galaxies: elliptical and lenticular, cD – galaxies: fundamental parameters – galaxies: formation – galaxies: evolution

1. Introduction

Ellipticals (Es) are among the most luminous and massive galaxies in the Universe. Together with lenticular (S0) galaxies, composed of a bulge, a stellar disk and often a stellar bar

component they form the vast category of early-type galaxies. Although, Es appear as a uniform class of galaxies, populating a planar distribution (the so-called Fundamental Plane) in the logarithmic parameter space defined by the central stellar velocity dispersion σ , the effective radius r_e and effective surface brightness I_e (see e.g. Djorgovski & Davis 1987), much evidence suggests that a secondary episode of star formation has occurred during their evolutionary history. Simulations indicate that galaxy collisions, accretion and merging episodes are important factors in the evolution of galaxy shapes (see e.g. Barnes 1996; Schweizer 1996) and can interfere with their passive evolution. This understanding of early-type galaxy

* Full appendix and Figs. 8 to 13 are only available in electronic form at <http://www.edpsciences.org>

** Full Tables 6, 7, 9 and 10 are only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/433/497>

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formation has been enhanced by the study of interstellar matter. This component and its relevance in secular galactic evolution was widely neglected in early studies of early-type galaxies since they were for a long time considered to be essentially devoid of interstellar gas. In the last two decades, however, multi-wavelength observations have changed this picture and have detected the presence of a multi-phase Inter Stellar Medium (ISM): a hot (10^7 K) and a warm (10^4 K) phase coexist and possibly interplay in several giant ellipticals. A cool (≈ 10 K) phase, detected in HI and CO, is also often revealed in early-type galaxies (Bettoni et al. 2001, and reference therein). Unlike spiral galaxies, the bulk of the gas in ellipticals is heated to the virial temperature, emitting in X-rays, and only comparatively small quantities are detected in the warm and cool phase of the interstellar medium (Bregman et al. 1992). The amount of X-ray emitting gas is related to the optical luminosity of the galaxy (White & Sarazin 1991), while no relation is found between the properties of the other components and the galaxy stellar luminosity. This latter fact may indicate that some amount of the gaseous material may indeed be of external origin. A pioneering spectroscopic study (Phillips et al. 1986), that examined the properties of a set of 203 southern E and S0 galaxies, began to shed light on the physical condition of the ionized gas in early-type galaxies. On the grounds of their analysis of the [NII 6583]/H α ratio they pointed out that, when line emission is present, it is confined to the nucleus and the properties of giant ellipticals are “indistinguishable” from a LINER nucleus (Heckman 1980). When the ionized region is imaged using narrow band filters centered at H α + [NII 6583], it appears extended with morphologies ranging from regular, disk-like structures to filamentary structures (see e.g. Demoulin-Ulrich 1984; Buson et al. 1993; Zeilinger et al. 1996; Macchetto et al. 1996) of several kpc in radius. The gaseous disks appear to be generally misaligned with respect to the stellar body of the galaxy suggesting an external origin for most of the gaseous matter. This picture is also supported by the observations of decoupled kinematics of gas and stars in a significant fraction of early-type galaxies (Bertola et al. 1992a). Notwithstanding the large amount of studies, our current understanding of the origin and the nature of the “warm” ionized gas in elliptical galaxies is still rather uncertain. The fact that the emission regions are always associated with dust absorption, even in the brightest X-ray systems, seems to exclude “cooling flows” as the origin of the ionized gas (see Goudfrooij 1998). The main ionization mechanism, which does not seem to be powered by star formation, however remains uncertain. Ionization mechanisms suggested range from photoionization by old hot stars – post-AGB and/or AGB-Manqué type objects (Binette et al. 1994) – or mechanical energy flux from electron conduction in hot, X-ray emitting gas (Voit 1991). Also ionization by a non-thermal central source is considered.

The present paper is the first of a series presenting a study of early-type galaxies in the nearby Universe showing emission lines in their optical spectra. Our aim is to improve the understanding of the nature of the ionized gas in early-type galaxies by studying its physical conditions, the possible ionization mechanisms, relations with the other gas components of the ISM and the connection to the stellar population of the host

galaxy. The adopted strategy is to investigate galaxy spectra of intermediate spectral resolution at different galactocentric distances and to attempt the modeling of their stellar populations to measure emission line properties. The study of stellar populations of early-type galaxies is of fundamental importance to the understanding of their evolution by the measurement of the evolution of the spectral energy distribution with time (see e.g. Buzzoni et al. 1992; Worthey 1992; González 1993; Buzzoni et al. 1994; Worthey et al. 1994; Leonardi & Rose 1996; Worthey & Ottaviani 1997; Trager et al. 1998; Longhetti et al. 1998a; Vazdekis 1999; Longhetti et al. 1999, 2000; Trager et al. 2000; Kuntschner et al. 2000; Beuing et al. 2002; Kuntschner et al. 2002; Thomas et al. 2003; Mehlert et al. 2003). Investigating issues such as the evolution of stellar populations and the ISM, we will explore the complex, evolving ecosystem within early-type galaxies and build a database of well studied galaxies to be used as a reference set for the study of intermediate and distant objects. Our target is to characterize the stellar populations, in particular those related to the extended emission region, in order to constrain hints about the galaxy formation/evolution history from the modeling of the complete (lines and continuum) spectrum characteristics. In this paper we present the sample, the observations and the data reduction and we discuss, through comparison with the literature, the database of line-strength indices we have measured. Forthcoming papers will analyze the emission region by tracing the properties as a function of the distance from the galaxy center. The paper is organized as follows. Section 2 introduces the sample and some of the relevant properties useful to infer the ionized gas origin and nature. Section 3 presents the observations, the data reduction and the criteria and the methods used for the selection of apertures and gradients extracted from the long slit spectra. Section 4 details the transformation of the line-strength indices to the Lick-IDS System and provides the database of line-strength indices measured at different galactocentric distances. In Sect. 5 we review the results, providing the database of line-strength indices measured at different galactocentric distances and discuss the comparison with the literature. The Appendix A provides a description/comments of individual galaxies in the sample.

2. Characterization of the sample

Our sample contains 50 early-type galaxies. The sample is selected from a compilation of galaxies showing ISM traces in at least one of the following bands: IRAS 100 μ m, X-ray, radio, HI and CO (Roberts et al. 1991). All galaxies belong to *Revised Shapley Ames Catalog of Bright Galaxies (RSA)* (Sandage & Tammann 1987) and have a redshift of less than 5500 km s $^{-1}$. The sample should then be biased towards objects that might be expected to have ongoing and recent star formation, at least in small amounts, because of the presence of emission lines. The emission should come from a combination of active galactic nuclei and star formation regions within the galaxies. Table 1 summarizes the basic characteristics of the galaxies available from the literature. Column 1 provides the identification; Cols. 2 and 3 the RA and Dec coordinates; Cols. 4 and 5 the galaxy morphological classifications according to the RSA

Table 1. Overview of the observed sample.

Ident.	RA (2000) Dec		RSA	RC3	PA	B_0	$(B - V)_0$	$(U - B)_0$	V_{hel}	r_e	ρ_{xyz}	ϵ
NGC 128	00 29 15.1	02 51 50	S02(8) pec	S0 pec sp	1	12.63	0.87	0.51	4227	17.3		0.67
NGC 777	02 00 14.9	31 25 46	E1	E1	155	12.23	0.99		5040	34.4		0.21
NGC 1052	02 41 04.8	-08 15 21	E3/S0	E4	120	11.53	0.89	0.44	1475	33.7	0.49	0.28
NGC 1209	03 06 03.0	-15 36 40	E6	E6:	80	12.26	0.90	0.40	2619	18.5	0.13	0.52
NGC 1297	03 19 14.2	-19 05 59	S02/3(0)	SAB0 pec:	3	12.61			1550	28.4	0.71	0.13
NGC 1366	03 33 53.7	-31 11 39	E7/S01(7)	S0 sp	2	12.81			1310	10.6	0.16	0.56
NGC 1380	03 36 27.3	-34 58 34	S03(7)/Sa	SA0	7	11.10	0.90	0.44	1844	20.3	1.54	0.41
NGC 1389	03 37 11.7	-35 44 45	S01(5)/SB01	SAB(s)0-:	30	12.39	0.89	0.39	986	15.0	1.50	0.37
NGC 1407	03 40 11.8	-18 34 48	E0/S01(0)	E0	35	10.93	0.89		1766	70.3	0.42	0.07
NGC 1426	03 42 49.1	-22 06 29	E4	E4	111	12.37	0.80	0.34	1443	25.0	0.66	0.34
NGC 1453	03 46 27.2	-03 58 08	E0	E2	45	12.59	0.92	0.56	3906	25.0		0.17
NGC 1521	04 08 18.9	-21 03 07	E3	E3	10	12.58	0.86	0.42	4165	25.5		0.35
NGC 1533	04 09 51.9	-56 07 07	SB02(2)/SBa	SB0-	151	11.65	0.89	0.46	773	30.0	0.89	0.19
NGC 1553	04 16 10.3	-55 46 51	S01/2(5)pec	SA(r)0	150	10.36	0.85	0.41	1280	65.6	0.97	0.38
NGC 1947	05 26 47.5	-63 45 38	S03(0) pec	S0- pec	119	11.75	0.93	0.44	1100	32.1	0.24	0.11
NGC 2749	09 05 21.4	18 18 49	E3	E3	60	13.03	0.87	0.44	4180	33.7		0.07
NGC 2911	09 33 46.1	10 09 08	S0p or S03(2)	SA(s)0: pec	140	12.53	0.91	0.43	3131	50.9		0.32
NGC 2962	09 340 53.9	05 09 57	RSB02/Sa	RSAB(rs)0+	3	12.71	1.00		2117	23.3	0.15	0.37
NGC 2974	09 42 33.2	-03 41 55	E4	E4	42	11.68	0.89	0.51	1890	24.4	0.26	0.38
NGC 3136	10 05 47.9	-67 22 41	E4	E:	40	11.42	0.60	0.23	1731	36.9	0.11	0.24
NGC 3258	10 28 54.1	-35 36 22	E1	E1	76	12.48	0.94	0.37	2778	30.0	0.72	0.13
NGC 3268	10 30 00.6	-35 19 32	E2	E2	71	12.57	0.94	0.41	2818	36.1	0.69	0.24
NGC 3489	11 00 18.3	13 54 05	S03/Sa	SAB(rs)+	70	11.13	0.74	0.34	693	20.3	0.39	0.37
NGC 3557	11 09 57.5	-37 32 22	E3	E3	30	11.23	0.86	0.48	3038	30.0	0.28	0.21
NGC 3607	11 16 54.3	18 03 10	S03(3)	SA(s)0:	120	11.08	0.88	0.43	934	43.4	0.34	0.11
NGC 3962	11 54 40.1	-13 58 31	E1	E1	15	11.61	0.89		1822	35.2	0.32	0.22
NGC 4552	12 35 39.8	12 33 23	S01(0)	E	92	10.80	0.95	0.54	322	29.3	2.97	0.09
NGC 4636	12 42 50.0	02 41 17	E0/S01(6)	E0-1	150	10.50	0.89	0.46	937	88.5	1.33	0.24
NGC 5077	13 19 31.6	-12 39 26	S01/2(4)	E3+	11	12.52	0.98	0.54	2764	22.8	0.23	0.15
NGC 5328	13 52 53.6	-28 29 16	E4	E1:	87	12.78	0.73		4671	22.2		0.31
NGC 5363	13 56 07.1	05 15 20	[S03(5)]	I0:	135	11.06	0.90	0.50	1138	36.1	0.28	0.34
NGC 5846	15 06 29.2	01 36 21	S01(0)	E0+	1	11.13	0.93	0.55	1709	62.7	0.84	0.07
NGC 5898	15 18 13.6	-24 05 51	S02/3(0)	E0	30	12.41	0.95		2267	22.2	0.23	0.07
NGC 6721	19 00 50.4	-57 45 28	E1	E+:	155	12.93	0.87	0.45	4416	21.7		0.15
NGC 6868	20 09 54.1	-48 22 47	E3/S02/3(3)	E2	86	11.72	0.91	0.52	2854	33.7	0.47	0.19
NGC 6875	20 13 12.4	-46 09 38	S0/a(merger)	SAB(s)0- pec:	22	12.66	0.82	0.29	3121	11.7		0.41
NGC 6876	20 18 19.0	-70 51 30	E3	E3	80	12.45	0.91	0.57	3836	43.0		0.13
NGC 6958	20 48 42.4	-37 59 50	R?S01(3)	E+	107	12.13	0.82	0.40	2652	19.8	0.12	0.15
NGC 7007	21 05 28.0	-52 33 04	S02/3/a	SA0-:	2	12.92	0.91	0.40	2954	15.4	0.14	0.42
NGC 7079	21 32 35.1	-44 04 00	SBa	SB(s)0	82	12.49	0.77	0.25	2670	19.8	0.19	0.32
NGC 7097	21 40 13.0	-42 32 14	E4	E5	20	12.48	0.88	0.42	2404	18.1	0.26	0.29
NGC 7135	21 49 45.5	-34 52 33	S01 pec	SA0- pec	47	12.61	0.91	0.45	2718	31.4	0.32	0.31
NGC 7192	22 06 50.3	-64 18 56	S02(0)	E+:	-	12.15	0.88	0.48	2904	28.6	0.28	0.15
NGC 7332	22 37 24.5	23 47 54	S02/3(8)	S0 pec sp	155	11.58	0.76	0.25	1207	14.7	0.12	0.75
NGC 7377	22 47 47.4	-22 18 38	S02/3/Sa pec	SA(s)0+	101	12.61	0.91	0.29	3291	36.9		0.19
IC 1459	22 57 10.6	-36 27 44	E4	E	40	10.96	0.90	0.54	1659	34.4	0.28	0.28
IC 2006	03 54 28.5	-35 57 58	E1	E	-	12.27	0.90	0.42	1350	28.6	0.12	0.15
IC 3370	12 27 38.0	-39 20 17	E2 pec	E2+	45	11.91	0.91	0.35	2934	38.6	0.20	0.21
IC 4296	13 36 39.4	-33 58 00	E0	E	40	11.43	0.90	0.54	3762	41.4		0.17
IC 5063	20 52 02.4	-57 04 09	S03(3)pec/Sa	SA(s)0+:	116	13.14	0.91	0.26	3402	26.7		0.28

Notes: The value of r_e of NGC 1297, NGC 6876 have been derived from ESO-LV (Lauberts & Valentijn 1989).

Fig. 1. Distribution of B -magnitudes (*first panel*), morphological types (*second panel*), heliocentric velocity (*third panel*) and galaxy density (*forth panel*).

(Sandage & Tamman 1987) and RC3 (de Vaucouleurs et al. 1991) respectively. Columns 6–9 give the position angle of the isophotes along major axis, the total corrected magnitude and the total $(B - V)$ and $(U - B)$ corrected colors from RC3 respectively. The heliocentric systemic velocity from HYPERCAT (<http://www-obs.univ-lyon1.fr/hypercat>) is reported in Col. 10. The effective radius, derived from A_e , the diameter of the effective aperture from RC3, is given in Col. 11. A measure of the richness of the environment, ρ_{xyz} (galaxies Mpc^{-3}), surrounding each galaxy is reported in Col. 12 (Tully 1988). Column 13 lists the average ellipticity of the galaxy as obtained from HYPERCAT.

Figure 1 summarizes the basic characteristics of the present sample, and, in particular in the fourth panel, provides evidence that a large fraction of galaxies are in low density environments. In the following subsection we summarize morphological and photometric studies of the ionized component which provide an insight of the overall galaxy structure. In Appendix A we complement the above information with individual notes on galaxies emphasizing kinematical studies of the ionized gas component, its correlation with the stellar body and its possible origin.

2.1. Imaging surveys of the ionized gas component

Buson et al. (1993) presented $H\alpha + [\text{NII}]$ imaging of a set of 15 nearby elliptical and S0 galaxies with extended optical emission regions. Nine are included in our sample, namely NGC 1453, NGC 1947, NGC 2974, NGC 3962, NGC 4636, NGC 5846, NGC 6868, NGC 7097 and IC 1459. In most of these galaxies the extended emission forms an inclined disk with ordered motions (Zeilinger et al. 1996). Furthermore the major axes of the stellar and the gaseous components appear frequently misaligned. In NGC 1453 the emission appears strongly decoupled from the stellar component and roughly aligned with the minor axis of the galaxy. In NGC 1947 the emission appears associated with a complex systems of dust lanes and shows several distinct knots. In NGC 2974 the ionized gas appears to lie in a fundamentally regular elongated structure with some peripheral fainter filaments (dust is also present). Buson et al. (1993) reported that for NGC 3962 the emission region consists of two distinct subsystems: an elongated central component strongly misaligned with both the major and minor axes of the stellar figure, and a peculiar extended arm-like structure departing from the major axis of the

internal disk, crossing the stellar body at an angle of 180° . Some dust is also noted. NGC 4636 has a ring-like emitting region extending asymmetrically around the galaxy nucleus. NGC 5846 shows complex, filamentary emission-line morphology, including an arm-like feature and dusty patches. NGC 6868 shows an elongated emitting region, with faint peripheral extensions and dust patches, which are strongly decoupled from the stellar component. NGC 7079 has elongated emission misaligned by about 30° with the stellar figure associated with dusty features. The ionized region of IC 1459 is aligned with the stellar major axis. Dust features for this latter galaxy have been identified by Goudfrooij (1994). A characterization of the extended emission region was attempted by Macchetto et al. (1996) who observed 73 luminous early-type galaxies selected from the RC3 catalogue. CCD images were obtained in broad R-band and narrow band images centered on the $H\alpha + [\text{NII}]$ emission lines. A set of 17 galaxies of our sample galaxies are in the Macchetto et al. set, namely NGC 1407, NGC 1453, NGC 3489, NGC 3607, NGC 3268, NGC 4552, NGC 4636, NGC 5077, NGC 5846, NGC 5898, NGC 6721, NGC 6868, NGC 6875, NGC 6876, NGC 7192, IC 1459 and IC 4296. The morphology of the extended emission has been divided into three categories. “SD” indicates galaxies with a small disk, extended on average less than 4 kpc (they adopt $H_0 = 55 \text{ km s}^{-1} \text{ Mpc}^{-1}$) with sometimes faint and short filaments. The ionized regions of NGC 1407, NGC 3268, NGC 3489, NGC 3607, NGC 4552 and NGC 4636 were classified as “SD”. “RE” indicates regular extended regions, similar to previous ones but extended between 4 and 18 kpc. NGC 1453, NGC 5077, NGC 5846, NGC 5898, NGC 6721, NGC 6868, NGC 6875, NGC 7192 and IC 1459 have extended ionized regions. “F” represents the detection of filaments and conspicuous filamentary structure which dominate the morphology and which depart from a more regular disk-like inner region. The filamentary structures extend as far as 10 kpc from the galaxy center. However, our sample contains no galaxies with a filamentary morphology. Macchetto and co-authors did not classify the ionized regions of NGC 6876 and IC 4296. From the above notes it appears that the ionized region of a large fraction of galaxies in our sample have a disk-like structure. A large number of kinematical studies (see individual notes in Appendix A) supports this hypothesis. In addition, it emerges that the ionized emission is always associated with dust absorption, even in the brightest X-ray systems (Goudfrooij 1994, 1998). Several classes of galaxies are

Table 2. Observing parameters.

	Run 1	Run 2
Date of Observations	March 98	September 98
Observer	Zeilinger W.	Zeilinger W.
Spectrograph	B & C grating #25	B & C grating #25
Detector	Loral 2K UV flooded	Loral 2K UV flooded
Pixel size (μm)	15	15
Scale along the slit ($''/\text{px}^{-1}$)	0.82	0.82
Slit length ($'$)	4.5	4.5
Slit width ($''$)	2	2
Dispersion ($\text{\AA mm}^{-1}$)	187	187
Spectral Resolution ($FWHM$ at $5200 \text{\AA}$) ($\text{\AA}$)	7.6	7.6
Spectral Range ($\text{\AA}$)	3550–9100	3550–9100
Seeing Range ($FWHM$) ($''$)	1.2–2	1.0–2.0
Standard stars	Feige 56	Ilt 1788, Ilt 377

present in the sample: interacting or post-interacting galaxies, galaxies showing evidence of kinematical decoupling between galaxy sub-components, elliptical galaxies with a dust lane along the minor axis, radio galaxies and galaxies hosting an AGN nucleus. To summarize the individual notes in Appendix A: (a) the sample contains four galaxies showing a shell structure (namely NGC 1553, NGC 4552, NGC 6958, NGC 7135). Twenty galaxies (namely NGC 128, NGC 1052, NGC 1407, NGC 1947, NGC 2749, NGC 3136, NGC 3489, NGC 4636, NGC 5077, NGC 5363, NGC 5846, NGC 5898, NGC 6868, NGC 7007, NGC 7097, NGC 7192, NGC 7332, IC 1459, IC 2006, IC 4296) have a peculiar kinematical behavior, i.e. rotation along the apparent minor axis, turbulent gas motions, counterrotation of star vs. gas and/or star vs. stars. In four galaxies (namely NGC 1052, NGC 1553, NGC 3962 and NGC 7332) multiple gas components have been detected.

3. Observations and data-reduction

3.1. Observations

Galaxies were observed during two separate runs (March and September 1998) at the 1.5 m ESO telescope (La Silla), equipped with a Boller & Chivens spectrograph and a UV coated CCD Fa2048L (2048×2048) camera (ESO CCD #39). Details of the observations and typical seeing conditions during each run are reported in Table 2. Table 3 provides a journal of observations i.e. the object identification (Cols. 1 and 5), the observing run (Cols. 2 and 6), the slit position angle oriented North through East (Cols. 3 and 7) and the total exposure time (Cols. 4 and 8). The spectroscopic slit was oriented along the galaxy major axis for most observations. He-Ar calibration frames were taken before and after each exposure to allow an accurate wavelength calibration to be obtained.

3.2. Data reduction

Pre-reduction, wavelength calibration and sky subtraction were performed using the IRAF¹ package.

A marginal misalignment between CCD pixels and the slit has been checked and corrected on each image by means of an “ad hoc” written routine. The wavelength range covered by the observations was $\approx 3550\text{--}9100 \text{\AA}$. Fringing seriously affected observations longward of $\approx 7300 \text{\AA}$. After accurate flat-fielding correction we considered the wavelength range $3700\text{--}7250 \text{\AA}$ for further use. Multiple spectra for a given galaxy were co-added. Relative flux calibration was obtained using a sequence of spectrophotometric standard stars. Before flux calibration, frames were corrected for atmospheric extinction, tailored to the ESO La Silla coefficients. The redshift value of each galaxy was directly measured from the lines of spectra. Spectra were finally de-redshifted to the rest frame. A set of representative spectra of the galaxies in the sample are presented in Fig. 2. The figure also shows the similarity of the two sides of the galaxy with respect to the nucleus: surprisingly after the geometrical and redshift corrections the two sides compare within few (2–3) percent, the major deviations due to the asymmetric distribution of the emission within the galaxies. For some galaxies, namely NGC 1947, NGC 2911, NGC 5328 and NGC 6875 there are serious differences between the two sides with respect to the nucleus since the spectrum is contaminated by the presence of a foreground star (see also next section).

3.3. Extraction of apertures and gradients

We have extracted flux-calibrated spectra along the slit in seven circular concentric regions, hereafter “apertures”, and in four adjacent regions, hereafter “gradients”. Aperture spectra were sampled with radii of $1.5''$, $2.5''$, $10''$, $r_c/10$, $r_c/8$, $r_c/4$ and $r_c/2$. Our aperture spectra are suitable for comparison with typical apertures commonly used in the literature both with different galaxies sample and with ongoing galaxy surveys (e.g. the SLOAN fiber spectra). The apertures were simulated by assuming that each radial point along the semi-major axis (sampled at both sides of our slit) is representative of the corresponding semi-ellipsis in the two-dimensional image. The galaxy ellipticity, ε is given in Table 1 Col. (13) and has been assumed to be constant with radius. With this trivial relation between a point within the simulated semi-circular apertures and the spectrum

¹ IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy Inc., under cooperative agreement with the National Science Foundation.

Table 3. Journal of galaxy observations.

Ident.	Run	Slit PA [deg]	t_{exp} [s]	Ident.	Run	Slit PA [deg]	t_{exp} [s]
NGC 128	2	1	2×1800	NGC 3962	1	15	2×1800
NGC 777	2	155	2×1800	NGC 4552	1	92	2×1800
NGC 1052	2	120	2×1800	NGC 4636	1	150	2×1800
NGC 1209	2	80	1×2400	NGC 5077	1	11	2×1800
NGC 1297	2	3	2×1800	NGC 5328	1	87	2×1800
NGC 1366	2	2	2×1800	NGC 5363	1	135	2×1800
NGC 1380	2	7	2×1800	NGC 5846	1	1	2×1800
NGC 1389	2	30	2×1800	NGC 5898	1	30	2×1800
NGC 1407	2	35	2×1800	NGC 6721	1,2	155	4×1800
NGC 1426	2	111	2×1800	NGC 6868	2	86	2×1800
NGC 1453	2	45	2×1800	NGC 6875	2	50	3×1800
NGC 1521	2	10	2×1800	NGC 6876	2	75	2×1800
NGC 1533	2	151	1×2400	NGC 6958	2	107	2×1800
NGC 1553	2	150	2×1800	NGC 7007	2	2	2×1800
NGC 1947	2	29	2×1800	NGC 7079	2	82	2×1800
NGC 2749	1	60	2×1800	NGC 7097	2	20	2×1800
NGC 2911	1	140	2×1800	NGC 7135	2	47	2×1800
NGC 2962	1	3	1×1800	NGC 7192	2	90	2×1800
NGC 2974	1	42	2×1800	NGC 7332	2	155	2×1800
NGC 3136	1	40	2×1800	NGC 7377	2	101	2×1800
NGC 3258	1	76	2×1800	IC 1459	2	40	2×1800
NGC 3268	1	71	2×1800	IC 2006	2	45	2×1800
NGC 3489	1	70	2×1800	IC 3370	1	45	2×1800
NGC 3557	1	30	2×1800	IC 4296	1	40	2×1800
NGC 3607	1	120	2×1800	IC 5063	2	116	2×1800

along the semi-major axis on the same side, we have calculated the average surface brightness spectrum and the corresponding *luminosity weighted* radius, r_l , of each semi-circular aperture. The average radius and the flux in each aperture are given by the formulae:

$$\langle r_l \rangle = \frac{\int r F_\lambda(r, \varepsilon) ds}{\int F_\lambda(r, \varepsilon) ds} \quad (1)$$

$$F_\lambda = \frac{\int F_\lambda(r, \varepsilon) ds}{\int ds} \quad (2)$$

where r , ε and s are the radius along the slit, the ellipticity and the area respectively. This procedure allow us to obtain a fair estimate of the aperture measurement corresponding to a mono-dimensional spectrum, in the lack of spectra along the minor axis (see e.g. González 1993, for a thorough discussion).

Simulated aperture spectra sample an increasing concentric circular region. However, the S/N of our spectra is enough to obtain information on the spatial gradients. To this purpose we have extracted spectra also in four adjacent regions along each semi-major axis, $0 \leq r \leq r_e/16$ (“nuclear”), $r_e/16 \leq r \leq r_e/8$, $r_e/8 \leq r \leq r_e/4$ and $r_e/4 \leq r \leq r_e/2$ providing the linear

average flux in the above interval. The average radius and the flux in each interval are given by the formulae:

$$\langle r_l \rangle = \frac{\int r F_\lambda(r) dr}{\int F_\lambda(r) dr} \quad (3)$$

$$F_\lambda = \frac{\int F_\lambda dr}{\int dr} \quad (4)$$

Figure 2 shows the spectra of the gradient of IC 1459 as a representative galaxy. Each panel displays the spectra extracted from the two symmetric sides with respect to the nucleus. The strategy of averaging the two sides of the spectrum with respect to the nucleus deserves few comments. Each single galaxy demonstrates to be quite homogeneous because in general the variations of the opposite sides are well within a few (2–3) percent in most of the cases. Even very faint features are well replicated in each side suggesting both that they are real photospheric features and a radial homogeneity of the stellar population.

In few cases, we notice that the emission features are less prominent (or even absent) in one side of the galaxy with respect to the other. The ionized gas component is less homogeneously distributed than the stellar component. This could suggest that the gas is not in an equilibrium configuration in the

Fig. 2. Spectra of a representative galaxy in the sample. The figure shows the gradients obtained sampling each long-slit spectrum in four regions: between $0 \leq r \leq r_e/16$ (indicated as “nuclear” in the figure), $r_e/16 \leq r \leq r_e/8$, $r_e/8 \leq r \leq r_e/4$ and $r_e/4 \leq r \leq r_e/2$. For each region the figure overplots the two opposite sides of the galaxies with respect to the nucleus. With the exclusion of few cases (see text), the two sides agree within few percent. The major difference between the two sides often reside in the emission line distribution which is not symmetric with respect to the nucleus.

potential well of the galaxy and possibly accreted from outside. An alternative explanation could be that the excitation mechanism is local (see also Appendix A). The study of the emission features as function of the distance from the galaxy center will be dealt with in a forthcoming paper.

Given the homogeneity of the side-spectra we present indices for the averaged spectra. However, due to the contamination of the spectrum by foreground stars we measured for NGC 1947, NGC 2911 and NGC 6875 apertures and gradients up to $r \leq r_e/8$, while for NGC 5328 we consider apertures and gradients up to $r \leq r_e/4$.

4. Measurements of line-strength indices and transformation to the Lick-IDS System

In the following sub-sections we detail the procedure we adopted to extract line-strength indices from the original spectra and to transform them into the Lick-IDS System.

We measured 21 line-strength indices of the original Lick-IDS system using the redefined passbands (see Table 2 in Trager et al. 1998 for the index definitions) plus 4 new line strength indices introduced by Worthey & Ottaviani (1997) (see their Table 1 for the index definitions; and Table 2 in Trager et al. 1998). In the subsequent analysis we then derived this set of 25 indices. We tested our index-measuring pipeline on the original Lick spectra comparing our measurements with the index values given by Worthey <http://astro.wsu.edu/worthey/html/system.html>.

4.1. Spectral resolution

Our spectral resolution ($FWHM \sim 7.6 \text{ \AA}$ at $\sim 5000 \text{ \AA}$) on the entire spectrum is slightly larger than the wavelength-dependent resolution of the Lick-IDS system (see Worthey & Ottaviani 1997). In order to conform our measures to the Lick-IDS System, we smoothed our data convolving each spectrum

Fig. 3. Comparison between central velocity dispersions used in this paper and in Trager et al. (1998). The lines indicate an average error (20 km s^{-1}) in the central velocity dispersion measurements.

(apertures and gradients) with a wavelength-dependent Gaussian kernel with widths given by the formula:

$$\sigma_{\text{smooth}}(\lambda) = \sqrt{\frac{FWHM(\lambda)_{\text{Lick}}^2 - FWHM(\lambda)_{\text{our}}^2}{8 \ln 2}}. \quad (5)$$

The selection of a Gaussian kernel is justified by the Gaussian shape of both our and Lick spectra (Worthey & Ottaviani 1997) absorption lines.

4.2. Correction for velocity dispersion

The observed spectrum of a galaxy can be regarded as a stellar spectrum (reflecting the global spectral characteristics of the galaxy) convolved with the radial velocity distribution of its stellar population. Therefore spectral features in a galactic spectrum are not the simple sum of its corresponding stellar spectra, because of the stellar motions. To measure the stellar composition of galaxies, we need to correct index measurements for the effects of the galaxy velocity dispersion (see e.g. G93, Trager et al. 1998; Longhetti et al. 1998a).

To this purpose, among the Lick stars observed together with the galaxies (see also Sect. 4.4), we have selected stars with spectral type between G8III and K2III (7 stars in our sample) typically used as kinematical templates in early-type galaxies. The list of the observed stars, as well as their spectral type, is given in Table 5. The stellar spectra (degraded to the Lick resolution) have been convolved with Gaussian curves of various widths in order to simulate different galactic velocity dispersions. We have considered a grid of velocity dispersion values in the range $(80\text{--}350) \text{ km s}^{-1}$. The values of velocity dispersion adopted for line-strength correction in the present paper are in agreement with those adopted by Trager et al. (1998), as shown in Fig. 3, and well within the above velocity dispersion range. On each convolved spectrum we have measured the 25 Lick-indices. The fractional index variations have been

derived for each velocity dispersion, σ , of our grid through an average on the selected stellar spectra:

$$R_{i,\sigma} = \frac{1}{N} \sum_{j=1}^N \left(\frac{EW_{i,j,\sigma} - EW_{i,j,0}}{EW_{i,j,0}} \right) \quad (6)$$

where N is the number of studied stars, $EW_{i,j,\sigma}$ is the i th index measured on the j th star at the velocity dispersion σ , and $EW_{i,j,0}$ is the measured index at zero velocity dispersion.

To compute the corrections for velocity dispersion, we derived at the radius of each aperture and gradient the corresponding σ value using the data listed in Table 4. The tabulated values characterize the trend of each galaxy velocity dispersion curve. For galaxies having only the central ($r_c/8$) value of σ we use this value also for the correction of the indices at larger radii (the tables of indices uncorrected for velocity dispersion are available, under request, to authors which may apply suitable corrections when new extended velocity dispersion curve measures will be available).

The new index corrected for the effect of velocity dispersion is computed in the following way:

$$EW_{i,\text{new}} = EW_{i,\text{old}} / (1 + R_{i,\text{sigma}}) \quad (7)$$

where $R_{i,\sigma}$ is determined by interpolation of the σ value on the grid of velocity dispersions.

4.3. Correction of the $H\beta$ index for emission

The presence of emission lines affects the measure of some line-strength indices. In particular, the $H\beta$ index measure of the underlying stellar population could be contaminated by a significant infilling due to presence of the $H\beta$ emission component.

González et al. (1993) verified a strong correlation between the $H\beta$ and the $[\text{OIII}]\lambda 5007$ emission in his sample, such that $EW(H\beta_{\text{em}})/EW([\text{OIII}]\lambda 5007) = 0.7$. Trager et al. (2000) examined the accuracy of this correlation by studying the $H\beta/[\text{OIII}]$ ratio supplementing the G93 sample with an additional sample of early-type galaxies with emission lines from the catalog of Ho, Filipenko & Sargent (1997). They found that the $H\beta/[\text{OIII}]$ ratio varies from 0.33 to 1.25, with a median value of 0.6. They propose that the correction to the $H\beta$ index is $\Delta H\beta = 0.6 EW([\text{OIII}]\lambda 5007)$.

The first step to measure the $EW([\text{OIII}]\lambda 5007)$ of the emission line is to degrade each spectrum (apertures and gradients) to the Lick resolution. The second, more delicate step, is to “build” a suitable template for the underlying stellar component and then adapt it to the galaxy velocity dispersion. At this purpose different methods have been adopted both using stellar and galaxy templates.

González (1993) used stellar templates. The adopted technique adopted consists in simultaneously fitting the kinematics and the spectrum of a galaxy with a library of stellar spectra. However, we are aware that absorption line spectra of early-type galaxies cannot be adequately fitted using Galactic stars or star clusters, the main reason being the high metallicity in giant ellipticals and the non-solar element ratios in ellipticals. To compute the emissions Goudfrooij (1998) suggested to use

Table 4. Velocity dispersion values adopted in the correction of line-strength indices.

Ident.	$\sigma_{re/8}$ [km s ⁻¹]	$\sigma_{re/4}$ [km s ⁻¹]	$\sigma_{re/2}$ [km s ⁻¹]	Ref.	Ident.	$\sigma_{re/8}$ [km s ⁻¹]	$\sigma_{re/4}$ [km s ⁻¹]	$\sigma_{re/2}$ [km s ⁻¹]	Ref.
NGC 128	183	–	–		NGC 3962	225	–	–	
NGC 777	317	272	266	JS89	NGC 4552	264	226	214	SP97b
NGC 1052	215	179	179	FI94	NGC 4636	209	202		CMP00
NGC 1209	240	195	178	PS98	NGC 5077	260	239	228	CMP00
NGC 1297	115	–	–		NGC 5328	303	–	–	
NGC 1366	120	–	–		NGC 5363	199	181	148	S83
NGC 1380	240	220	198	DO95	NGC 5846	250	228	190	CMP00
NGC 1389	139	–	–		NGC 5898	220	183	172	CMP00
NGC 1407	286	–	–		NGC 6721	262	245	171	B94
NGC 1426	162*	157	121	PS97a	NGC 6868	277	235	220	CMP00
NGC 1453	289	–	–		NGC 6875	–	–	–	
NGC 1521	235	236	206	PS98	NGC 6876	230	–	–	
NGC 1533	174	–	–		NGC 6958	223	171	137	L98
NGC 1553	180	142	–	L98,R88	NGC 7007	125	–	–	
NGC 1947	142	142	142	BGZ92	NGC 7079	155	125	85	BG97
NGC 2749	248	221	–	JS89	NGC 7097	224	234	196	C86
NGC 2911	235	–	–		NGC 7135	231*	239	–	L98
NGC 2962	197	168	119	PS00	NGC 7192	257	247	266	CD94
NGC 2974	220	170	130	CvM94	NGC 7332	136	127	116	SP97c
NGC 3136	230	180		KZ00	NGC 7377	145	–	–	
NGC 3258	271	313	264	KZ00	IC 1459	311	269	269	FI94
NGC 3268	227	155	–	KZ00	IC 2006	122	–	–	CDB93
NGC 3489	129	116	115	CMP00	IC 3370	202	146	127	J87
NGC 3557	265	247	220	FI94	IC 4296	340	310	320	S93
NGC 3607	220	210	195	CMP00	IC 5063	160	–	–	

Notes: The average central value, obtained from the on-line compilation HYPERCAT (<http://www-obs.univ-lyon1.fr/hypercat/>), is adopted for $\sigma_{re/8}$. Values at $\sigma_{re/4}$ and $\sigma_{re/2}$ velocity dispersion values are obtained from references quoted in Cols. 5 and 10. Legend: DO95 = D’Onofrio et al. (1995); SP97a = Simien & Prugniel (1997a); SP97b = Simien & Prugniel (1997b); PS97 = Prugniel & Simien (1997); PS00 = Prugniel & Simien (2000); PS98 = Prugniel & Simien (1998); FI94 = Fried & Illingworth (1994); Z96 = Zeilinger et al. (1996); JS89 = Jedrzejewski & Schechter (1989); R88 = Rampazzo (1988); L98 = Longhetti et al. (1998b); BGZ92 = Bertola et al. (1992a); CMP00 = Caon et al. (2000); KZ00 = Koprolin & Zeilinger (2000); CDB93 = Carollo et al. (1993); S83 = Sharples et al. (1983); B94 = Bertin et al. (1994); V87 = Varnas et al. (1987); C86 = Caldwell et al. (1986); CD94 = Carollo & Danziger (1994); J87 = Jarvis (1987); BG97 = Bettoni & Galletta (1997); S93 = Saglia et al. (1993); CvM94 = Cinzano & van der Marel (1994).

a suitable template galaxy spectrum of an elliptical. Following his suggestion we then considered galaxies in our sample that, according to our observed spectrum and the combined information coming from the literature, show neither evidence in their spectrum of neither emission features nor of dust, usually associated with the gas emission (see Goudfrooij 1998), in their image. To this purpose we adopted NGC 1426 spectrum as a template for an old population: this choice is motivated both by the lack of emission line in its spectrum and by the absence of dust features in high resolution HST images obtained by Quillen et al. (2000) (see Appendix A). We then proceeded in following way: we smoothed the template spectrum to adapt it to the velocity dispersion of the galaxy region under exam and normalized it to the galaxy continuum on both sides of H α line.

All spectra (aperture and gradients) have been analyzed using the template in the corresponding region. NGC 1426 has a low value of velocity dispersion consistently with its low Mg₂ index; this indicates that it is not a giant elliptical and may be representative of the metal poor tail in our sample. Given the anti-correlation between H β index and Mg₂ index strength one may wonder whether this galaxy is the suitable template for all the sample. In order to check the reliability of the use of this template we have compared the H α absorption profile of NGC 1426 with that of NGC 1407, which belongs to upper tail of the Mg₂ σ relation. Once adopted the above procedure of smoothing and normalization we notice that the residual difference in the H α profile implies a negligible difference in the computed *EW* H β correction (≈ 0.03 Å).

Fig. 4. (Left four panels) Comparison between the correction estimate of the $H\beta$ emission derived from [OIII] emission line and from the $H\alpha$ emission (see Sect. 4.3). The solid line is the one-to-one relation assuming for O[III] valid the formula $EW(H\beta_{em})/EW([OIII]\lambda 5007) = 0.7$. The comparison is shown in the four regions sampled by the linear gradients (legend: lg1 ($0 \leq r \leq r_e/16$ (“nuclear”)), lg2 ($r_e/16 \leq r \leq r_e/8$), lg3 ($r_e/8 \leq r \leq r_e/4$) and lg4 ($r_e/4 \leq r \leq r_e/2$)). Open circles indicate galaxies which O[III] emission is detected under 1σ level, triangles and full squares between 1 and 2σ levels and above 2σ level respectively (see text). (Right four panels) Fitting of N[II](λ 6548, 6584) and $H\alpha$ lines for two representative galaxies: one with $H\alpha$ in emission (NGC 2749) and the second with the $H\alpha$ infilling (IC 2006). Lower panels show the residuals lines after the subtraction of the $H\alpha$ line of the template galaxy NGC 1426 (dotted lines in the upper panels).

We characterized the emission as the flux in excess with respect to the template within the bandpass (4996.85–5016.85) centered at 5007 Å, while the continuum is defined by a blue (4885.00–4935.00) and a red (5030.00–5070.00) bandpass (González 1993):

$$EW_{em} = \int_{\lambda_1}^{\lambda_2} \frac{F_R - F_{temp}}{F_C} d\lambda \quad (8)$$

where F_R , F_{temp} and F_C are the galaxy, the template and the continuum fluxes respectively. According to this definition, detected emissions result as negative EWs. Considering the ([OIII] λ 5007) emissions detected above 1σ (the variance of the spectrum), we derived the EW of the $H\beta$ emission from the equation $\Delta H\beta = 0.7 EW([OIII]\lambda 5007)$. The derived corrections for $H\beta$ could be easily compared with González (1993) for the three galaxies in common (namely NGC 1453, NGC 4552 and NGC 5846). We obtained an 0.48 (vs. 0.89 ± 0.06), 0.02 (vs. 0.25 ± 0.05) and 0.09 (vs. 0.39 ± 0.08) i.e. systematically smaller corrections as if our template had a residual gas infilling, but which is not confirmed by imaging observations as outlined above. We tested also the use of a stellar template taken from our observed Lick stars, the main problem being that our set of stars is very “limited” with respect to that of Lick stellar library used by González. The use of stellar templates (K giant stars) in our sample, maintaining the above O[III] bandpasses, implies a worse match of the spectral features in our galaxy sample than if we adopt NGC 1426 as a template. Finally this results in a systematically higher $H\beta$ corrections, at least for the galaxies in common with González.

The large wavelength coverage of our spectra permits us to measure also the $H\alpha$ emission and allows a further estimate of

the $H\beta$ emission according to the relation $F_{H\beta} = 1/2.86 F_{H\alpha}$ (see e.g. Osterbrock 1989).

The measurement of the $H\alpha$ emission is not straightforward in our spectra since the line is blended with the ([NII] λ 6548, 6584) emission lines. To derive the $H\alpha$ emissions we fitted each galaxy spectrum (apertures and gradients) with a model resulting from the sum of our template galaxy spectrum and three Gaussian curves of arbitrary widths and amplitudes (see Fig. 4). Once derived the $H\beta$ emitted fluxes from Eq. (8) we computed the pseudo-continua in $H\beta$ according to the bandpass definition of Trager et al. (1998) and used them to transform flux measures into EWs.

In Fig. 4 (left panels) we plot the comparison between the two different estimates computed in the four gradients. The points in the figure do not include the Seyfert 2 galaxy IC 5063 for which the $\Delta H\beta$ as derived from the [OIII] emission is significantly higher than the value resulting from $H\alpha$ emission.

The new $H\beta$ index, corrected for the emission infilling, is computed from the non raw one according to the formula $EW(H\beta_{corr}) = EW(H\beta_{raw}) - H\beta_{em}$, where $EW(H\beta_{corr})$ is the corrected value obtained applying the $H\beta_{em}$ estimate derived from the [OIII] emission using as template the galaxy NGC 1426. This latter estimate is *statistically similar* to that obtained from the $H\alpha$ correction as shown in Fig. 4, although the use of $H\alpha$ estimate for emission correction will be widely discussed in a forthcoming paper.

Tables 6 and 7 report the values of the $H\beta$ correction for the apertures and gradients derived from $EW([OIII])$ and $H\alpha$ (complete tables are given in electronic form at the CDS).

Table 5. Lick standard stars.

Ident.	Spectral type	Numb. obser.s
HD 165195	K3p	1
HD 172401	K0III	1
HD 23430	A0	2
HR 6159	K4III	2
HR 6710	F2IV	1
HR 6770	G8III	1
HR 6868	M0III	1
HR 7317	K4III	2
HR 3145	K2III	3
HR 3418	K1III	3
HR 3845	K2.5III	1
HR 4287	K1III	2
HR 5480	G7III	1
HR 5582	K3III	2
HR 5690	K5III	1
HR 5888	G8III	1
HR 6299	K2III	1

Table 6. H β corrections for apertures.

Galaxy	aperture	EW[OIII]	Quality	EWH α
NGC 128	0	-0.263	2.000	-0.558
NGC 128	1	-0.210	1.000	-0.532
NGC 128	2	-0.205	1.000	-0.481
NGC 128	3	-0.182	1.000	-0.465
NGC 128	4	-0.053	0.000	-0.325
NGC 128	5	0.006	0.000	-0.301
NGC 128	6	0.036	0.000	-0.186
NGC 777	0	0.039	0.000	-0.126
NGC 777	1	0.077	0.000	-0.114
NGC 777	2	0.060	0.000	-0.100
NGC 777	3	0.076	0.000	-0.103
NGC 777	4	0.112	0.000	-0.113
NGC 777	5	0.144	0.000	-0.124
NGC 777	6	0.071	0.000	-0.124
.....				

The table provides in Col. 2 the number of the aperture, the correspondent radius of which is given in Table 9, and the estimate of the EW of the O[III] and H α (Cols. 3 and 5 respectively) obtained from the subtraction of the template galaxy, NGC 1426. Column 4 gives the quality of the measure, obtained as the ratio between the estimated emission ($F_{\text{gal}} - F_{\text{templ}}$) and the variance of the spectrum in the O[III] wavelength region, σ_λ . When the emission is lower than the variance the quality is set to 0. When the emission is between 1 and $2\sigma_\lambda$ or larger than $2\sigma_\lambda$ the quality is set to 1 and 2 respectively. The entire table is given in electronic form at the CDS.

4.4. Lick-IDS standard stars

After the indices have been homogenized to the Lick-IDS wavelength dependent resolution, corrected for emission and velocity dispersion, we still have to perform a last step to transform our line-strengths indices into the Lick system. To this purpose we followed the prescription given by Worthey & Ottaviani (1997) and observed, contemporary to the galaxies, a sample of 17 standard stars of different spectral type common to the Lick library. The observed stars, together with the corresponding number of observations and the spectral type,

Table 7. H β corrections for gradients.

Galaxy	Aperture	EW[OIII]	Quality	EWH α
NGC 128	0	-0.317	1.000	-0.702
NGC 128	1	-0.204	1.000	-0.608
NGC 128	2	-0.173	2.000	-0.434
NGC 128	3	0.119	0.000	-0.174
NGC 777	0	0.042	0.000	-0.124
NGC 777	1	0.057	0.000	-0.106
NGC 777	2	0.045	0.000	-0.168
NGC 777	3	0.162	0.000	-0.129
....	...			

The table provides in Col. 2 the gradient, ($0 = 0 \leq r \leq r_e/16$, $1 = r_e/16 \leq r \leq r_e/8$, $2 = r_e/8 \leq r \leq r_e/4$ and $3 = r_e/4 \leq r \leq r_e/2$), and the estimate of the EW of the O[III] and H α (Cols. 3 and 5 respectively) obtained from the subtraction of the template galaxy, NGC 1426. Column 4 gives the quality of the measure, obtained as the ratio between the estimated emission ($F_{\text{gal}} - F_{\text{templ}}$) and the variance of the spectrum in the O[III] wavelength region, σ_λ . When the emission is lower than the variance the quality is set to 0. When the emission is between 1 and $2\sigma_\lambda$ or larger than $2\sigma_\lambda$ the quality is set to 1 and 2 respectively. The entire table is given in electronic form at the CDS.

are given in Table 5. Once the stellar spectra have been degraded to the wavelength-dependent resolution of the Lick system, we have measured the line-strength indices with the same procedure adopted for the galaxy spectra. We compared our measures with the Lick-IDS indices reported by Worthey et al. (1994) for the standard stars. The deviations of our measures from the Lick system are parametrized through a *robust straight-line fit* (see e.g. Numerical Recipes 1992) which avoid an undesired sensitivity to outlying points in two dimension fitting to a straight line. The functional form is $EW_{\text{Lick}} = \beta + \alpha \times EW_{\text{our}}$ where EW_{our} and EW_{Lick} are respectively our index measure on the stellar spectrum and the Lick value given in Worthey et al. (1994).

Figure 5 shows the comparison between the Lick indices and our measures for the observed standard stars. The dotted line represent the one to one relation while the solid line is the derived fit. For each index we report the coefficients α and β of the fit in Table 8. Notice that for the majority of the indices α value is very close to 1 and only a zero-point correction is required (see also Puzia et al. 2002), although serious deviations from the one-to-one relation are shown by Ca lines 4227 and 4455 and Fe 4531.

4.5. Estimate of indices measurement errors

In order to obtain the errors on each measured index we have used the following procedure. Starting from a given extracted spectrum (aperture or gradient at different galactocentric distances), we have generated a set of 1000 Monte Carlo random modifications, by adding a wavelength dependent Poissonian fluctuation from the corresponding spectral noise, $\sigma(\lambda)$. Then, for each spectrum, we have estimated the moments of the distributions of the 1000 different realizations of its indices.

Fig. 5. Comparison of passband measurements from our spectra and original Lick data for 17 Lick standard stars. The dotted line is the one to one relation while the solid line is the *robust straight-line fit* to the filled squares.

5. Results

For each galaxy the set of 25 indices obtained for the 7 apertures and the 4 gradients are provided in electronic form at the CDS with the format shown in Tables 9 and 10 respectively. The structure of the above tables is the following: each aperture (or gradient) is described by two rows. In the first row: Col. 1 gives the galaxy identification, Col. 2 the number of the aperture, Col. 3 is a flag: 0 stands for values of indices, Cols. 4 and 5 give the radii delimited by the aperture, from Cols. 6 to 30 individual indices are given. In the second row: Col. 1 gives the galaxy identification, Col. 2 the number of the aperture, Col. 3 is a flag: 1 stands for error of the indices, Cols. 4 and 5 give the luminosity weighted radius of the aperture and the adopted equivalent radius, from Cols. 6 to 30 are given the errors of the indices.

In electronic form, by request to the authors, the tables of raw indices (before the velocity dispersion correction) are also available as well as the fully calibrated spectra (apertures and gradients) in digital form for each galaxy.

In Figs. 8–13 we show as examples the trend with radius of the Mg_2 , Fe(5335) and $H\beta$ indices for the 50 galaxies in the sample (apertures are marked with open squares, gradient with dots).

5.1. Comparison with the literature

A significant fraction, about 60%, of galaxies in the present sample has one previous measurement in the Lick-IDS system but basically restricted within the $r_e/8$ region. Line-strength measures obtained both from apertures and gradients outside this area and within the $r_e/8$ region, with the present radial mapping, are completely new.

The set of line-strength indices in the literature available for a comparison is quite heterogeneous since indices are measured within different apertures. Furthermore, there are many possible sources of systematic errors from seeing effects to the calibration applied to shift indices to the same spectrophotometric system and to velocity dispersion correction.

Table 8. α and β coeff. for index correction.

Index	α	β	Aver. disp.	Unit
CN ₁	1.059	0.023	0.025	mag
CN ₂	1.035	0.030	0.023	mag
Ca4227	1.317	0.408	0.396	Å
G4300	1.105	0.179	0.310	Å
Fe4383	0.963	1.169	0.772	Å
ca4455	0.451	1.844	0.341	Å
Fe4531	1.289	-0.299	0.437	Å
Fe4668	0.976	0.128	0.653	Å
H β	1.064	-0.196	0.166	Å
Fe5015	1.031	0.804	0.396	Å
Mg ₁	1.014	0.015	0.009	mag
Mg ₂	0.998	0.020	0.012	mag
Mgb	1.014	0.417	0.241	Å
Fe5270	1.058	0.270	0.240	Å
Fe5335	0.990	0.356	0.249	Å
Fe5406	1.005	0.282	0.151	Å
Fe5709	1.321	-0.270	0.174	Å
Fe5782	1.167	-0.075	0.165	Å
NaD	1.003	0.027	0.245	Å
TiO ₁	0.997	0.004	0.006	mag
TiO ₂	1.003	-0.001	0.008	mag
H δ_A	1.136	-0.622	1.087	Å
H γ_A	0.990	0.518	0.734	Å
H δ_F	1.059	-0.036	0.503	Å
H γ_F	1.011	0.458	0.745	Å

Three galaxies, namely NGC 1453, NGC 4552 and NGC 5846 are in the González (1993) sample. Three galaxies, namely NGC 1553, NGC 6958 and NGC 7135 belong to the sample observed by Longhetti et al. (1998a). Twenty one galaxies are in the sample provided by Trager et al. (1998) namely NGC 128, NGC 777, NGC 1052, NGC 1209, NGC 1380, NGC 1407, NGC 1426, NGC 1453, NGC 1521, NGC 2749, NGC 2962, NGC 2974, NGC 3489, NGC 3607, NGC 3962, NGC 4552, NGC 4636, NGC 5077, NGC 5328, NGC 7332 and NGC 7377. Eleven galaxies are in the sample recently published by Beuing et al. (2002), namely IC 1459, IC 2006, NGC 1052, NGC 1209, NGC 1407, NGC 1553, NGC 5898, NGC 6868, NGC 6958, NGC 7007 and NGC 7192.

A global comparison with the literature is shown in Fig. 6. In detail: (1) with Longhetti et al. (1998a) the comparison is made with indices computed on the aperture of $2.5''$ radius; (2) with González (1993) on $r_e/8$ aperture; and (3) with Trager et al. (1998) with indices computed within standard apertures; (4) with Beuing et al. (2002) with indices computed on the aperture with radius $r_e/10$, taking into account that these authors did not correct H β for emission infilling.

In Table 11 we present a summary of the comparison with the literature. Both the offset and the dispersion for the various indices in the table are comparable (or better) of those obtained

on the same indices by Puzia et al. (2002) in their spectroscopic study of globular cluster.

The comparison of our data with Trager et al. (1998) for each index is in general better than that with other authors and, in particular, with Beuing et al. (2002).

The comparison with Trager et al. (1998) shows a zero point shift for Mgb values, our data being larger although within the dispersion. A large shift is also shown by G4300 and Ca4227 both also visible in the comparison with Lick stellar indices. Beuing et al. (2002) indices are on consistent range of values, although some systematic effects and zero point offsets are present. While there is a good agreement with the H β (without emission correction), Mg₁, Mg₂ and Fe5335 line-strength indices, Mgb and Fe5270 show a large zero point differences and dispersion. Beuing et al. (2002) provided a comparison with Trager et al. (1998), on a partially different sample. They show a basic agreement for the H β , Mg₁, Mg₂ and Mgb (although both a zero point shift and a different slope are visible, e.g. in H β and Mg₁) while Fe5270, and Fe5335 indices show a quite large dispersion and zero point shift as shown in our Fig. 6.

The well known Mg₂ vs. σ relation is plotted in Fig. 7. Our Mg₂ values computed at the $r = 1.5''$, compatible with the SLOAN apertures are plotted versus the corresponding velocity dispersion values. Adopting the parameters of the fitting given in Worthey & Collobert (2003) (their Table 1), the dotted line is the least-square fit obtained by Bernardi et al. (1998) on the sample of 631 field early-type galaxies while the solid line is the Trager et al. (1998) fit. Bernardi et al. fit is made on the Mg₂ index computed using the Lick definition but not transformed to the Lick-IDS system. The long-dashed line shows our least-squares fits to the present data: notice that the value of the Mg index at $\sigma = 300 \text{ km s}^{-1}$ of 0.339 is well consistent with that of Trager et al. (1998) while the slope for our small set of galaxies is in between those given by the above considered authors.

6. Summary

This paper is the first in a series dedicated to the spectroscopic study of early-type galaxies showing emission lines in their optical spectrum. It presents the line-strength index measurements for 50 galaxies residing in cosmological environments of different galaxy richness. The morphology and the kinematics of the gas component with respect to the stellar population are summarized using the available literature in order to characterize each galaxy for subsequent studies. According to current views supported by numerical simulations (see e.g. Colless et al. 1999) a large fraction of the galaxies in the sample display morphological and/or kinematical signatures of past interaction/accretion events. For each galaxy, three integrated spectra for different galactocentric distances, center, $r_e/4$ and $r_e/2$, have been measured. Spectra, in the wavelength range of $3700 \text{ Å} < \lambda < 7250 \text{ Å}$, have been collated in the Atlas which covers a large set of E and S0 morphological classes.

The paper is dedicated to the characterization of the emission galaxy underlying stellar population through the preparation of a data base of their line-strength indices in the Lick-IDS

Table 9. Fully corrected line-strength indices for the apertures.

Galaxy	iz	ie	r_1	r_2	CN ₁	CN ₂	Ca4227	G4300	Fe4383	Ca4455	Fe4531	Fe4668	H β	Fe5015	Other
Galaxy	iz	ie	r_1	r_e	eCN ₁	eCN ₂	eCa4227	eG4300	eFe4383	eCa4455	eFe4531	eFe4668	eH β	eFe5015	indices
NGC 128	0	0	0.000	0.087	0.136	0.167	1.830	6.150	5.790	2.330	4.150	7.580	1.460	5.860	...
NGC 128	0	1	0.055	17.300	0.003	0.004	0.054	0.087	0.149	0.079	0.139	0.225	0.099	0.198	...
NGC 128	1	0	0.000	0.100	0.136	0.166	1.830	6.150	5.850	2.340	4.150	7.610	1.410	5.880	...
NGC 128	1	1	0.062	17.300	0.003	0.004	0.054	0.087	0.149	0.080	0.139	0.226	0.098	0.198	...
NGC 128	2	0	0.000	0.125	0.135	0.165	1.830	6.150	5.950	2.350	4.160	7.660	1.440	5.910	...
NGC 128	2	1	0.076	17.300	0.003	0.004	0.054	0.087	0.150	0.080	0.141	0.223	0.099	0.198	...
NGC 128	3	0	0.000	0.145	0.135	0.164	1.840	6.150	5.980	2.350	4.150	7.680	1.420	5.950	...
NGC 128	3	1	0.087	17.300	0.003	0.004	0.055	0.087	0.151	0.080	0.141	0.224	0.099	0.199	...
NGC 128	4	0	0.000	0.250	0.132	0.159	1.760	6.120	5.910	2.300	4.090	7.630	1.310	5.970	...
NGC 128	4	1	0.142	17.300	0.003	0.004	0.056	0.090	0.154	0.082	0.144	0.225	0.098	0.206	...
NGC 128	5	0	0.000	0.289	0.131	0.158	1.770	6.120	5.920	2.300	4.100	7.640	1.300	6.000	...
NGC 128	5	1	0.161	17.300	0.003	0.004	0.056	0.091	0.155	0.083	0.145	0.228	0.099	0.207	...
NGC 128	6	0	0.000	0.500	0.125	0.151	1.760	6.090	5.970	2.300	4.130	7.670	1.340	6.090	...
NGC 128	6	1	0.260	17.300	0.003	0.004	0.059	0.095	0.160	0.086	0.152	0.237	0.103	0.216	...
NGC 777	0	0	0.000	0.044	0.176	0.215	2.410	6.030	5.050	2.290	3.910	8.820	1.150	6.220	...
NGC 777	0	1	0.028	34.400	0.002	0.003	0.046	0.083	0.131	0.070	0.122	0.181	0.079	0.176	...
NGC 777	1	0	0.000	0.073	0.175	0.212	2.050	6.100	4.940	2.290	4.030	8.450	1.200	6.260	...
NGC 777	1	1	0.045	34.400	0.004	0.004	0.055	0.104	0.174	0.090	0.163	0.243	0.107	0.227	...
NGC 777	2	0	0.000	0.100	0.173	0.209	1.870	6.120	4.980	2.340	4.050	8.360	1.210	6.190	...
NGC 777	2	1	0.059	34.400	0.004	0.004	0.053	0.101	0.168	0.086	0.158	0.235	0.104	0.220	...
NGC 777	3	0	0.000	0.125	0.167	0.205	1.870	6.160	5.140	2.400	3.990	8.240	1.270	6.170	...
NGC 777	3	1	0.072	34.400	0.002	0.003	0.046	0.080	0.127	0.065	0.115	0.174	0.075	0.165	...
NGC 777	4	0	0.000	0.145	0.165	0.203	1.870	6.160	5.160	2.440	3.940	8.150	1.300	6.200	...
NGC 777	4	1	0.081	34.400	0.002	0.003	0.045	0.080	0.127	0.065	0.115	0.175	0.075	0.165	...
NGC 777	5	0	0.000	0.250	0.159	0.194	1.860	6.250	5.070	2.470	3.820	8.220	1.190	6.230	...
NGC 777	5	1	0.125	34.400	0.002	0.003	0.046	0.077	0.123	0.064	0.115	0.169	0.073	0.164	...
NGC 777	6	0	0.000	0.500	0.174	0.199	1.920	6.440	5.640	2.530	3.960	7.910	1.400	6.310	...
NGC 777	6	1	0.210	34.400	0.005	0.005	0.074	0.130	0.216	0.108	0.204	0.298	0.131	0.293	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

The complete Table 9 is given in electronic form at the CDS.

Table 10. Fully corrected line-strength indices for the gradients.

Galaxy	iz	ie	r_1	r_2	CN ₁	CN ₂	Ca4227	G4300	Fe4383	Ca4455	Fe4531	Fe4668	H β	Fe5015	Other
Galaxy	iz	ie	r_1	r_e	eCN ₁	eCN ₂	eCa4227	eG4300	eFe4383	eCa4455	eFe4531	eFe4668	eH β	eFe5015	indices
NGC 128	0	0	0.000	0.063	0.140	0.167	1.580	6.020	4.840	2.160	3.820	7.080	1.540	5.520	...
NGC 128	0	1	0.031	17.300	0.004	0.005	0.077	0.132	0.219	0.112	0.191	0.318	0.127	0.262	...
NGC 128	1	0	0.063	0.125	0.137	0.168	1.790	6.150	5.680	2.290	4.210	7.570	1.340	5.830	...
NGC 128	1	1	0.093	17.300	0.003	0.004	0.053	0.094	0.149	0.079	0.157	0.234	0.104	0.200	...
NGC 128	2	0	0.125	0.250	0.130	0.160	1.800	6.160	6.060	2.330	4.010	7.740	1.560	5.940	...
NGC 128	2	1	0.182	17.300	0.003	0.004	0.054	0.094	0.148	0.080	0.153	0.237	0.103	0.199	...
NGC 128	3	0	0.250	0.500	0.138	0.162	1.850	6.030	6.110	2.340	4.130	7.630	1.330	6.330	...
NGC 128	3	1	0.359	17.300	0.003	0.004	0.057	0.101	0.158	0.084	0.163	0.252	0.108	0.211	...
NGC 777	0	0	0.000	0.063	0.175	0.213	2.280	5.980	4.990	2.270	3.970	8.820	1.210	6.140	...
NGC 777	0	1	0.029	34.400	0.003	0.004	0.063	0.114	0.194	0.094	0.163	0.267	0.104	0.233	...
NGC 777	1	0	0.063	0.125	0.170	0.206	1.670	6.170	5.130	2.450	4.100	8.130	1.210	6.180	...
NGC 777	1	1	0.090	34.400	0.003	0.003	0.047	0.083	0.136	0.066	0.117	0.185	0.076	0.184	...
NGC 777	2	0	0.125	0.250	0.146	0.180	1.760	6.250	5.000	2.530	3.700	8.120	1.230	6.330	...
NGC 777	2	1	0.177	34.400	0.003	0.004	0.056	0.094	0.155	0.078	0.139	0.211	0.095	0.212	...
NGC 777	3	0	0.250	0.500	0.189	0.210	2.040	7.080	5.970	2.430	4.060	7.880	1.830	5.970	...
NGC 777	3	1	0.347	34.400	0.004	0.005	0.076	0.131	0.218	0.108	0.193	0.299	0.123	0.302	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

The complete Table 10 is given in electronic form at the CDS.

Fig. 6. Comparison of index measurements of González (1993: open triangles), Trager (1998: full squares), Longhetti et al. (1998: open circles), Beuing et al. (2002: open pentagons) with our data. Solid lines mark the one-to-one relation. Table 11 summarizes the results of the comparison.

Fig. 7. Mg_2 versus σ relation. Our Mg_2 line-strength indices measured within the SLOAN aperture ($r = 1.5''$) are plotted after the transformation to the Lick-IDS system. The solid dashed line is the least-square fit obtained Trager et al. (1998). The dotted and long-dashed lines represent the least-square fit obtained by Bernardi et al. (1998) for the field sample of 631 galaxies and our fit (value at $\sigma_{300 \text{ km s}^{-1}} = 0.339$, slope of relation = 0.214) to the present data respectively.

system once corrected for several effects including infilling by emission and velocity dispersion.

For each object we extracted 7 luminosity weighted apertures (with radii: $1.5''$, $2.5''$, $10''$, $r_e/10$, $r_e/8$, $r_e/4$ and $r_e/2$) corrected for the galaxy ellipticity and 4 gradients ($0 \leq r \leq r_e/16$, $r_e/16 \leq r \leq r_e/8$, $r_e/8 \leq r \leq r_e/4$ and $r_e/4 \leq r \leq r_e/2$). For each aperture and gradient we measured 25 line-strength indices: 21 of the set defined by the Lick-IDS “standard” system (Trager et al. 1998) and 4 introduced by Worthey & Ottaviani (1997).

Line-strength indices, in particular those used to build the classic $H\beta - \langle MgFe \rangle$ plane, have been compared with the literature. A direct comparison was made with González (1993), Longhetti et al. (1998a), Beuing et al. (2002) but in particular with the larger data sets of Trager et al. (1998) showing the reliability of our measures.

In forthcoming papers we plan (1) to model this information to investigate the ages and metallicities of the bulk of the stellar populations in these galaxies; (2) to extend the study calibrating and modeling other “blue indices” outside the Lick/IDS system namely $\Delta(4000 \text{ Å})$ (Hamilton 1985), $H+K/(\text{CaII})$ and $H\delta/\text{FeI}$ (Rose 1984, 1985) correlated with the age of the last starburst event in each galaxy; (3) to complete the study of the emission line component on a finer spatial grid.

Table 11. Comparison with the literature.

Index	N_{gal}	Offset	Dispersion	Units
G93 + Long98				
Hb	6	0.171	0.886	Å
Mg ₂	6	-0.006	0.014	mag
Mgb	6	0.078	0.458	Å
Fe5270	6	0.208	0.334	Å
Fe5335	6	0.160	0.348	Å
Mg ₁	6	-0.007	0.011	mag
Trager et al. (1998)				
Hb	20	-0.031	0.405	Å
Mg ₂	20	0.004	0.016	mag
Mgb	20	0.218	0.321	Å
Fe5270	21	0.051	0.333	Å
Fe5335	21	-0.038	0.376	Å
Mg ₁	20	-0.002	0.013	mag
G4300	21	0.463	0.946	Å
Ca4227	21	0.519	0.757	Å
Beuing et al. (2002)				
Hb	11	-0.059	0.271	Å
Mg ₂	11	0.018	0.025	mag
Mgb	11	0.470	0.628	Å
Fe5270	11	0.339	0.603	Å
Fe5335	11	0.075	0.455	Å
Mg ₁	11	0.011	0.018	mag

Offsets and dispersions of the residuals between our data and the literature. Dispersions are 1σ scatter of the residuals. Beuing et al. (2002) do not compute G4300 and Ca4227 indices. For G4300 and Ca4227 indices González (1993) and Longhetti et al. (1998) used a (slightly) different definition than Trager et al. (1998) and consequently comparisons are not reported in the table. The comparison for H β index between our data and those of Trager et al. (1998) and Beuing et al. (2002) are made using uncorrected data.

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Fig. 8. Fully corrected Mg_2 line-strength index as function of the luminosity weighted radius normalized to the galaxy equivalent radius R_e . Apertures are indicated with open squares, while gradients are indicated with full dots.

Fig. 9. As in Fig. 8.

Fig. 10. Fully corrected $H\beta$ line-strength index as function of the luminosity weighted radius normalized to the galaxy equivalent radius R_e . Apertures are indicated with open squares, while gradients are indicated with full dots.

Fig. 11. As in Fig. 10.

Fig. 12. Fully corrected Fe5335 line-strength index as function of the luminosity weighted radius normalized to the galaxy equivalent radius R_e . Apertures are indicated with open squares, while gradients are indicated with full dots.

Fig. 13. As in Fig. 12.

Appendix A: Relevant notes on individual galaxies from the literature

We report in this section some studies relevant to the present investigation performed in the recent literature with particular attention to the properties of the ionized gas with respect to the bulk of the stellar component.

NGC 128 Emsellem & Arsenault (1997) present a study of the gas (and dust) disk tilted at an angle of 26° with respect to the major axis of the galaxy. The stellar and gas velocity fields show that the angular momentum vectors of the stellar and gaseous components are reversed, suggesting that the gas component orbits suffer the presence of a tumbling bar, possibly triggered by the interaction of NGC 128 with the nearby companion NGC 127. The gas extends at least up to $6''$ from galaxy center, and in the inner parts line ratios are typical of LINER and consistent with the gas being ionized by post-AGB stars. D’Onofrio et al. (1999) evaluate the central gas mass is $\approx 2.7 \times 10^4 M_\odot$. The dust does not have the same distribution as the gas but is largely confined to the region of interaction between NGC 128 and NGC 127. They calculated a dust mass of $\approx 6 \times 10^6 M_\odot$ for NGC 128.

NGC 777 The kinematics and the photometry of this galaxy were obtained by Jedrzejewski & Schechter (1989). Both the PA and the ellipticity profile appear nearly constant at about 149° and 0.18 respectively. Both the kinematics along the major and minor axes have been investigated. A rotation of about 50 km s^{-1} is measured along the major axis while no apparent rotation is detected along the minor one.

NGC 1052 The galaxy is known as a prototypical LINER (Heckman 1980). Plana et al. (1998), performing Fabry-Perot observations, succeeded in disentangling two gas components both kinematically decoupled from the stellar component. Both, in fact, have their apparent major axis nearly perpendicular to the stellar one. The ionized gas of the main component was detected up to $30''$ from the center, while the second one extends up to $15''$. The main component shows rotation with an apparent major axis of $45^\circ \pm 4^\circ$ similar to that of the HI emission detected by van Gorkom et al. (1986) with which it shares also similar kinematical characteristics. The velocity field of both components presents shapes and velocity dispersion in agreement with models of inner disks found in elliptical galaxies. Recently Gabel et al. (2000) imaged the central part of the galaxy using WFPC2/HST with an $H\alpha$ filter showing that a filamentary nebular emission extends about $1''$ around a compact nucleus with a more diffuse halo extending to further distances. At the position angle of $\approx 235^\circ$ there is a narrow filament of $H\alpha$ emission. A radio jet/lobe at a position angle of $\approx 275^\circ$ has been evidenced by Wrobel & Heeschen (1984). The emission line region is much more extended, as discussed above. Gabel et al. (2000) examined whether or not the ionizing continuum flux is sufficient to power the above extended emission line region. They conclude that a pure-central source photo-ionization model with the simplest non-thermal continuum (a simple power law) reproduces the emission line flux in the inner region of NGC 1052. Other processes, such as shocks or photoionization by stars, are not required to produce the observed emission. However, the contribution of these

latter mechanisms cannot be ruled out in the extended nebular emission region. Recently Raiman et al. (2001) have analyzed the spectra of NGC 1052 and IC 1459, classified as LINERS, at several galactocentric distances from the nucleus. They found that these objects have both the nucleus redder than the surroundings and nuclear absorption lines stronger than outside the nucleus similarly to normal galaxies. On the other side the spectral synthesis of NGC 1052 and IC 1459 indicate that they have only a $\approx 10\text{--}20\%$ larger contribution of the 1-Gyr component at the nucleus with respect to normal galaxies which are dominated by the old metal rich component whose contribution is decreasing outwards. The above authors exclude the presence of young massive stars found by Maoz et al. (1998).

NGC 1209 The galaxy is part of the group dominated by NGC 1199. The surface photometry and the geometrical study, performed by Capaccioli et al. (1988), extends up to $\mu_B \approx 28 \text{ mag arcsec}^{-2}$. The ellipticity grows from 0.22 to 0.57 with basically no twisting ($\langle \text{PA} \rangle = 51^\circ \pm 2^\circ$ up to $126''$) suggesting that the galaxy is an S0.

NGC 1380 D’Onofrio et al. (1995) suggest the presence of a dusty nucleus. The stellar component has a strong gradient in both rotation and velocity dispersion curves and the disk dominates outside $20''$. Kuntschner (2000), studying stellar populations of early-type galaxies in the Fornax cluster, found that this bright lenticular has properties similar to those of ellipticals suggesting that they experienced similar star formation histories. NGC 1380 exhibits an overabundance in magnesium compared to iron, similarly to most ellipticals in the Fornax cluster.

NGC 1389 This galaxy belongs to the Fornax cluster. Phillips et al. (1996) examined the nucleus of the galaxy using the HST Planetary Camera, finding no evidence for an unresolved central point source. The image shows a smooth light distribution sharply peaked at the center and isophote twisting within $5''$.

NGC 1407 The $(B - V)$ image of this galaxy, which is a radio source, reveals a circumnuclear ring slightly redder than the nucleus (Goudfrooij 1994). The stellar kinematics were studied along several axes by Longo et al. (1994). Franx et al. (1989) found significant rotation along the minor axis.

NGC 1426 The study performed by Capaccioli et al. (1988) extends up to $\mu_B \approx 28 \text{ mag arcsec}^{-2}$ and indicates that the galaxy is an S0 with basically no isophotal twisting ($\langle \text{PA} \rangle = 105^\circ \pm 1^\circ$ up to $100''$). Quillen (2000) have observed the galaxy with HST NICMOS. The central $10''$ show very regular isophotes with no twisting or deviations from elliptical shapes. The core has a power law profile and no dust features are detected. The extended rotation curve and velocity dispersion profiles, obtained by Simien & Prugniel (1997a), do not show any peculiarities.

NGC 1453 Pizzella et al. (1997) found that this E2 galaxy has a twisting of 10° . The $H\alpha$ image reveals the presence of an ionized disk misaligned with respect to the stellar isophotes by $\approx 56^\circ$ suggesting an intrinsic triaxial shape.

NGC 1521 The surface photometry and the geometrical study performed by Capaccioli et al. (1988) extends up to $\mu_B \approx 27\text{--}28 \text{ mag arcsec}^{-2}$ at $3.8 r_e$. The galaxy shows a peculiar light distribution with a change in slope along the major

axis and a significant twisting ($\approx 20^\circ$ up to $126''$). The extended rotation curve and velocity dispersion profiles, obtained by Simien & Prugniel (1997a), do not show peculiar features.

NGC 1553 The galaxy belongs to the shell galaxies sample of Malin & Carter (1983). The galaxy kinematics is typical of an early S0s and shows two maxima in the rotations curve (Kormendy 1984; Rampazzo 1988; Longhetti et al. 1998b). No rotation is found along the minor axis. The $H\alpha$ narrow band image of this galaxy (Trinchieri et al. 1997) shows a strong nuclear peak and a bar-like feature $\approx$ in the North-South direction that ends in spiral structure at $8''$ from the nucleus. Blanton et al. (2001) proposed using *Chandra* data that the center of NGC 1553 is probably an obscured AGN while, the X-ray diffuse emission exhibits significant substructure with a spiral feature passing through the center of the galaxy. Longhetti et al. (1998a, 1999, 2000) studied the stellar population of this galaxy suggesting that the age of a secondary burst is old, probably associated to the shell formation. Rampazzo et al. (2003) measured the velocity field of the gas component using Fabry-Perot data. In the central region of NGC 1553 the ionized gas is co-rotating with the stellar component.

NGC 1947 The galaxy is considered a minor-axis dust-lane elliptical (Bertola et al. 1992b). The stellar component of this galaxy is rotating around the minor axis, perpendicularly to the gas rotation axis. The gas component forms a warped disk whose external origin is suggested by Bertola et al. (1992b).

NGC 2749 The galaxy, studied by Jedrzejewski & Schechter (1989), shows strong rotation ($\geq 100 \text{ km s}^{-1}$) along both the major and minor axes. A measure of the gas rotation curve was attempted using the $\lambda 5007 \text{ \AA}$ line. They suggested that the gas is not rotating, with an upper limit of the order of one-half the stellar rotation velocity on either axis.

NGC 2911 Known also as Arp 232 the galaxy is classified as a LINER in the Vèron-Cetty & Vèron (2001) catalog. Michard & Marchal (1994) suggest that this is a disk dominated S0 with a significant dust component.

NGC 2962 The extended rotation curve and velocity dispersion profiles, obtained by Prugniel & Simien (2000), do not show peculiarities.

NGC 2974 This E4 galaxy imaged in $H\alpha$ reveals the presence of an ionized disk misaligned with respect to the stellar isophotes by $\approx 20^\circ$ (Pizzella et al. 1997; Ulrich-Demoulin et al. 1984; Goudfrooij 1994). The galaxy has an HI disk (Kim 1989) with the same rotation axis and velocity as the inner ionized one. Plana et al. (1998) suggest that this object is a good candidate for an internal origin of the ionized gas. Bregman et al. (1992) present evidence of a spiral arm structure and Cinzano & van der Marel (1994) could not discard the hypothesis that NGC 2974 is a Sa galaxy with an unusually low disk-to-bulge ratio.

NGC 3136 Using an $H\alpha + [\text{NII}]$ image Goudfrooij (1994) detected an extended emission with a maximum at the nucleus and peculiar arm-like feature extending out to $\approx 55''$ from the center. Dust absorption is found to be associated with the ionized gas. Koprolin & Zeilinger (2000) suggest that a counterrotating disk with a dimension of $2''$ is located $4''$ from the galaxy center.

NGC 3258 Koprolin & Zeilinger 2000 measured a very low rotation velocity of $39 \pm 10 \text{ km s}^{-1}$ for this galaxy.

NGC 3268 Koprolin & Zeilinger (2000) found that the galaxy has an asymmetric rotation curve with respect to the nucleus, probably due to the presence of a dust-lane.

NGC 3489 Gas and stars show a fast rotation along the major axis of the gas distribution which roughly coincides with the major axis of the stellar isophotes. The gas shows rotation along the minor axis while no stellar rotation is measured. There is evidence for a distinct nuclear stellar component (within $r \approx 3''$) (Caon et al. 2000).

NGC 3557 The color map reveals a possible ring of dust near the center of the galaxy (Colbert et al. 2001). The galaxy is a double tail radio source with a central knot and a jet (Birkinshaw & Davies 1985). Goudfrooij (1994), using an $H\alpha + [\text{NII}]$ image, shows that the outer isophotes of the line emission twist gradually toward the apparent major axis of the galaxy.

NGC 3607 Caon et al. (2000) observe stellar kinematics along the major axis which is also the major axis of the gas distribution. The gas rotation curve has a steeper gradient and a larger amplitude than the stellar one.

NGC 3962 Birkinshaw & Davies (1985) revealed a radio source in the center of the galaxy. The morphology and the kinematics of the ionized gas confirm the presence of two distinct subsystems: an inner gaseous disk and an arc-like structure. The inner gaseous disk shows regular kinematics with a major axis near $\text{PA} = 70^\circ$ and inclination of about 45° (Zeilinger et al. 1996).

NGC 4552 The extended kinematics of this galaxy has been recently obtained by Simien & Prugniel (1997b) who measure a very low maximum rotation velocity of $17 \pm 10 \text{ km s}^{-1}$. NGC 4552 is a member of the Malin & Carter (1983) supplementary list of galaxies showing shells (they report “two or three shells and jet”).

NGC 4636 Caon et al. (2000) observed the galaxies along three axes and found that the gas has very irregular velocity curves. Zeilinger et al. (1996) suggested that the gas could suffer for turbulent motions due to material not yet settled.

NGC 5077 Caon et al. (2000) found that the galaxy exhibits a gaseous disk with major axis roughly orthogonal to the galaxy photometric major axis. The gas isophotes show a twisting and a warp (Pizzella et al. 1997). The gas has a symmetric rotation curve with an amplitude of 270 km s^{-1} at $r = 13''$. Along this axis the stellar rotation is slow. Along the axis at $\text{PA} = 10^\circ$, the stellar velocity curve shows a counterrotation in the core region ($r < 5''$) with a corresponding peak in the stellar velocity dispersion.

NGC 5266 This galaxy has a dust lane along the apparent minor axis of the elliptical stellar body. The kinematics of NGC 5266 has been extensively studied by Varnas et al. (1987) revealing a cylindrical rotation of the stellar component ($V_{\text{max}} = 212 \pm 7 \text{ km s}^{-1}$) about the short axis and smaller rotation ($V = 43 \pm 16 \text{ km s}^{-1}$) about the long axis. The stellar velocity rotation is $210 \pm 6 \text{ km s}^{-1}$ and decreases with radius to 100 km s^{-1} at $r \approx 20''$. The gas associated with the dust rotates about the major axis of the galaxy with a velocity of $260 \pm 10 \text{ km s}^{-1}$. In the warp the gas motion are prograde with

respect to the major axis stellar rotation. HI radio observations reveal the presence of a large amount of cold gas probably distributed in a rotating disk.

NGC 5363 The galaxy has a warped dust lane confined to the central part along its apparent minor axis. Differently from NGC 5128, the gas motions in the warp are found to be retrograde with respect to the stellar body. Bertola et al. (1985) suggest that is an indication that the warp is a transient feature and of the external origin of the gas and dust system.

NGC 5846 Ulrich-Demoulin et al. (1984) have studied the ionized gas component in this galaxy. Several studies suggests the presence of dust (see Goudfrooij 1998) in the galaxy. Caon et al. (2000) found that the gas shows an irregular velocity profile, while stars have very slow rotation.

NGC 5898 Caon et al. (2000) analyzed the stellar and the gas kinematics up to $45''$ showing the existence of a stellar core of $5''$ in radius, aligned with the major axis, which counterrotates with respect to the outer stellar body. The ionized gas counterrotates with respect to the inner stellar core and corotates with respect to outer stellar body. At the same time, the gas counterrotates along the minor axis, indicating that the angular momentum vectors of the stars and of the gas are misaligned, but not anti-parallel. A moderate quantity of dust is also present.

NGC 6721 Bertin et al. (1994) obtained extended stellar kinematics (to $0.8 r_e$) for this object finding a sizeable rotational velocity $\approx 120 \text{ km s}^{-1}$.

NGC 6868 The Fabry-Perot study of Plana et al. (1998) shows that the line-of-sight velocity field of the ionized gas component has a velocity amplitude of $\pm 150 \text{ km s}^{-1}$. Caon et al. (2000) show that along the axes at $\text{PA} = 30^\circ$ and 70° the gas and stars have similar kinematical properties, but along $\text{PA} = 120^\circ$ the gas counterrotates with respect to the stellar component. Zeilinger et al. (1996) noticed the presence of an additional inner gas component which suggested could be due to the superposition of two unresolved counterrotating components, one dominating the inner region, the other dominating the outer parts. Also stars show a kinematically-decoupled counterrotating core. The stellar velocity dispersion decreases towards the galaxy center.

NGC 6958 This galaxy belongs to the list of Malin & Carter (1983) of southern shell early-type. Saraiva et al. (1999) detected isophotal twisting of about 100° ($\approx 70^\circ$ in the inner $5''$) but no particular signature of interaction in the isophote shape which is elliptical. They conclude that if the galaxy suffered interaction, the companion galaxy has probably already merged.

NGC 7007 Pizzella et al. (1997) found that the disk is misaligned by about 30° with respect to the stellar isophotes with an inclination of 57° . The ionized gas disk counterrotates with respect to the stellar body and a bow-shape dust lane is also visible on the eastern side (Bettoni et al. 2001).

NGC 7079 A counterrotating disk-like structure of ionized gas within $20''$ from the center has been detected by Bettoni & Galletta (1997). The stellar body kinematics is typical of an undisturbed disk. Cool gas (CO) has been detected by Bettoni et al. (2001). The cool gas component shares the same kinematics of the ionized gas.

NGC 7097 Caldwell et al. (1986) found that the gas and stellar components counterrotate. Zeilinger et al. (1996) show that the rotation curve of the gaseous disk have a steep central gradient with a discontinuity in the central part which may be related to the counterrotating stellar component.

NGC 7135 The galaxy belongs to the list of shell galaxies in the southern hemisphere compiled by Malin & Carter (1983). Longhetti et al. (1998ab, 1999, 2000) studied the inner kinematics and the stellar population of this galaxy. Rampazzo et al. (2003) show that the gas corotates with the stellar body.

NGC 7192 Carollo & Danziger (1994) showed that the innermost $8''$ region counterrotates with respect to the galaxy body at greater radii. The authors report that in correspondence with the kinematically decoupled core an enhancement in the Mg_2 index is observed, while iron lines are only weakly enhanced with respect to measurements at greater radii. The surface photometry shows that the galaxy has a very regular, round structure.

NGC 7332 Plana & Boulesteix (1996), using a Fabry-Perot (CIGALE), found two gas components (see also NGC 1052). The velocity field is consistent with two counterrotating emission systems.

IC 1459 This giant elliptical has a massive counterrotating stellar core ($M \approx 10^{10} M_\odot$; Franx & Illingworth (1988) which hosts a compact radio source. The galaxy is also crossed by a disk of ionized gas (see Sect. 2.1), whose emission is detected out to $35''$ and rotates in the same direction as the outer stellar component but at a higher speed (350 km s^{-1}). Therefore counterrotation in this galaxy seems confined to the inner core and affects only stars. Bettoni et al. (2001) detect $^{12}\text{CO}(J = 2-1)$ emission decoupled both from the ionized gas and the counterrotating stellar core, since the velocity centroid of the CO emission is redshifted by about 100 km s^{-1} with respect to the galaxy systemic velocity. Raimann et al. (2001) presented spectral syntheses at several galacto-centric distances (see notes for NGC 1052).

IC 2006 A faint emission of ionized gas, characterized by a velocity gradient which is smaller and inverted with respect to that of stars, is detected within $25''$ of the nucleus. The counterrotating ionized gas disk is highly turbulent with a measured velocity dispersion of 190 km s^{-1} (Schweizer et al. 1989). Kuntschner (2000) found that IC 2006 has stronger metal-line absorption than what would be expected from the mean index- σ_0 relation for ellipticals, although from their data it is not clear if the galaxy is too metal-rich or whether the central velocity dispersion is lower than for other ellipticals of the same mass.

IC 3370 The galaxy is a box shaped elliptical, with a prominent dust-lane in the inner region, showing evidence of cylindrical rotation and X-shaped isophotes. Van Driel et al. (2000) postulated that it is a candidate polar-ring galaxy.

IC 4296 The galaxy kinematics have been studied by Franx et al. (1989) and more recently by Saglia et al. (1993) out to $0.8 r_e$ confirming the counterrotating core, detected by previous authors. Saglia et al. suggest the presence of a diffuse dark matter halo.

IC 5063 Long-slit spectroscopy for the radio galaxy IC 5063 has uncovered a clear rotation pattern for the gas close to the nucleus and a flat rotation curve further out, to at least

19 kpc (Bergeron et al. 1983). The velocity difference between the two flat parts of the rotation curve on both sides of the nucleus is $\Delta V = 475 \text{ km s}^{-1}$. Colina et al. (1991) report a very high excitation emission line spectrum for this early-type galaxy which hosts a Seyfert 2 nucleus that emits particularly strongly at radio wavelength. The high excitation lines are detected within $1\text{--}1.5''$ of both sides of the nucleus, which is approximately the distance between the radio core and both of the lobes. These lines indicate the presence of a powerful and hard ionizing continuum in the general area of the nucleus and the radio knots in IC 5063. It has been estimated (Morganti et al. 1998) that the energy flux in the radio plasma is an order of magnitude smaller than the energy flux emitted in the optical emission lines. The shocks associated with the jet-ISM interaction are, therefore, unlikely to account for the overall ionization, and the NLR must be, at least partly, photo-ionized by the nucleus, unless the lobe plasma contains a significant thermal component.